The Distance to Community Medical Care and the Likelihood of Hospitalization: Is Closer Always Better?

ABSTRACT

Objectives. This study examined the influence that distance from residence to the nearest hospital had on the likelihood of hospitalization and mortality.

Methods. Hospitalizations were studied for Maine, New Hampshire, and Vermont during 1989 (adults) and for 1985 through 1989 (children) and for mortality (1989) in Medicare enrollees.

Results. After other known predictors of hospitalization (age, sex, bed supply, median household income, rural residence, academic medical center, and presence of nursing home patients) were controlled for, the adjusted rate ratio of medical hospitalization for residents living more than 30 minutes away was 0.85 (95% confidence interval [CI] = 0.82, 0.88) for adults and 0.78 (95% CI = 0.74, 0.81) for children, compared with those living in a zip code with a hospital. Similar effects were seen for the four most common diagnosis-related groups for both adults and children. The likelihood of hospitalization for conditions usually requiring hospitalization and for mortality in the elderly did not differ by distance.

Conclusions. Distance to the hospital exerts an important influence on hospitalization rates that is unlikely to be explained by illness rates. (*Am J Public Health.* 1997;87: 1144–1150)

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Introduction

For many years, federal and state policy has sought to increase the local availability of medical care through such programs as the Hill-Burton Act[1] and the National Health Service Corps.[2] These programs, as well as the greater overall supply of physicians, have successfully increased the geographic availability of medical care for many communities. Nevertheless, distance to medical care remains highly variable, an inevitable consequence of dispersed populations and medical services.

Closer medical care is highly valued by patients and their families. A hospital or physician located within one's own community saves travel and offers a sense of security. From a clinician's perspective, patients who live closer to hospitals and physicians should require fewer hospitalizations. If the condition of such patients worsens, they can more easily return; physicians, patients, and their families should be more comfortable with outpatient treatment of conditions in which the need for hospitalization is uncertain. Other things being equal, patients who live farther from the hospital would be expected to have higher hospitalization rates than those who live closer.

Only a few studies have examined the relationship between distance to medical care and the use of health care services. In general, these studies have examined the effect of distance on patients' utilization of particular medical facilities.[3–9] Jarvis observed in 1851 the decay of utilization of "lunatic hospitals" with distance.[10] More recent studies have focused on utilization rates for specific conditions, such as cancer therapy,[11–16] and procedures associated with myocardial infarction.[17] The studies found that utilization of these specific services is increased by their local availability. Whether populations that live farther from hospitals are more or less likely to use the hospital for medical causes of admission has not been examined.

In this study, we examine the relationships between distance from home residence to the nearest hospital and primary care physician (community medical care) and hospitalization rates. We also analyze the relationship between distance to community medical care and overall mortality rates in the elderly. These analyses were conducted for the population of northern New England (Maine, New Hampshire, and Vermont), a region with small metropolitan areas, a large rural population, and three academic medical centers. Prior population-based analyses of health care in this region have led to important insights confirmed by other studies.[15,18–21] Our findings raise new questions about the utilization of hospital services across population groups.

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Methods

Overview of Study Design

We used a cross-sectional design to study hospitalization and mortality rates for the population residing in the 72 hospital service areas of Maine, New Hampshire, and Vermont (northern New England). The primary unit of analysis was the age–sex stratum in each of the 1045 zip codes. The study period was 1989 for adults and 1985 through 1989 for children; the longer study period for children was necessary since hospital discharges were less frequent. We defined hospital service areas using patient-origin studies, which assigned patients' zip codes to hospital service areas in such a way that the majority of services to the resident population were provided by the hospitals located within each hospital service area.[22]

Hospital Discharge Data

We obtained hospital discharge data from the Maine Health Care Finance Commission (Augusta), New Hampshire Department of Health and Human Services (Concord), and the Vermont Department of Health (Burlington). The files included all discharges for the study area population occurring in hospitals within the three states and the adjacent state of Massachusetts. Discharges occurring in New York hospitals along the western border of Vermont were not included (< 1% of Vermont discharges; personal communication, John Gauthier, Vermont Department of Health, August 1993).

Hospital Discharge Study Conditions

We examined aggregate medical diagnosis-related groups and the four most common diagnosis-related groups for pediatric (aged < 18 years; perinatal conditions excluded) and adult (aged ≥ 18 years) conditions separately. For adults, the diagnosis-related groups were heart failure and shock (127), angina (140), medical back (243), and esophagitis/gastroenteritis without complications (183), and for children, bronchitis/asthma (98), esophagitis/gastroenteritis (184), simple pneumonia (91), and viral illness and fever of unknown origin (422). These diagnosis-related groups have highly variable discharge rates across geographic areas, which implies that outpatient treatment is often possible.[23,24] In addition, we examined four adult conditions for which there is greater agreement among physicians that patients require hospitalization—acute myocardial infarction, cerebral vascular accident, major cancer surgery, and hip fracture.[25] Rates for these conditions vary less among geographic locations,[26] and we refer to these conditions as low-variation conditions.

Medicare Mortality Data

Mortality studies were restricted to the Medicare population because the zip code of residence is needed to determine distance and is not included in mortality vital statistics. Medicare enrollment and deaths were determined from the 100% denominator file (Health Care Financing Administration, Baltimore, Maryland) for calendar year 1989. Enrollees were included if they were aged 65 years or older at any time during 1989 and had a residence zip code within the three states' hospital service areas.

Study Population Characteristics

Discharge records included age and gender for each hospitalized patient while counts of the at-risk population were available only by 5-year age and sex groups for zip codes (Donnelley Marketing, Inc, Stamford, Conn). These zip code–level age–sex strata served as the unit of analysis (n = 8510 for adults, 8360 for children). For each such stratum, we computed the total number of discharges and the total population at risk. The median population within zip code age–sex strata was 88 for adults and 149 for children. We attributed to each stratum the characteristics of the corresponding zip code (travel time, median household income, metropolitan or nonmetropolitan status) and the hospital service area (per capita bed supply, presence of an academic medical center) within which the zip code was located.

We calculated travel times from each zip code to both the nearest primary care physician and the nearest hospital. The American Hospital Association[27] provided the location of acute-care general hospitals, and the American Medical Association and the American Osteopathic Association provided files with physician practice zip code and self-designated specialty. Primary care was defined as family practice and general internal medicine for adults, and family practice and general pediatrics for children. The nearest point on a road to each zip code's geographic center was designated the travel terminus. We computed travel times using digitized road maps (in conjunction with Tactics International, Andover, Mass) and weighting for various road categories and level of traffic congestion to derive a travel time, measured in minutes. If a zip code included the nearest hospital or physician, it was assigned a travel time of 0 minutes.

The number of staffed acute-care beds per capita of total population for each hospital service area was used as the measure of available inpatient resources.[27] The total, rather than age-specific (pediatric, adult), bed supply was used since the few institutions with separate pediatric units in northern New England used pediatric and adult beds interchangeably when the need arose. Academic medical centers within the study region were located in Burlington, Vermont; Hanover, New Hampshire; and Portland, Maine. Each of these hospitals served as a regional medical facility and had more than one graduate medical education program. Because previous work has shown that rural residents are more likely to be hospitalized than urban residents,[2] we classified the study area's zip codes as metropolitan (designated Metropolitan Statistical Areas by the Office of Management and Budget) or nonmetropolitan.[28] In northern New England, metropolitan areas are small city–suburban aggregates, with populations ranging from 88 141 for Lewiston-Auburn, Maine, to 223 578 for Portsmouth-Dover-Rochester, New Hampshire–Maine.

The zip codes having nursing home patients for residents aged 65 years and older were obtained from the 1990 decennial census.[29] Zip code–level census data were not available for 194 zip codes, and these were excluded from the adult analyses (< 2% of total discharges).

Statistical Methods

We used Poisson regression[30] to study the relationship between travel time and the likelihood of hospitalization. For example, this statistical procedure produced an estimate of the hospitalization rate in residents living more than 30 miles from a hospital relative to those living in a zip code with a hospital. The dependent variable was the discharge rate within each zip code–age–sex stratum; we were not able to distinguish multiple hospitalizations of the same patient. Separate regression models were performed for each study condition. Each model controlled for age (4 categories for children and 5 for adults), sex, travel time to nearest hospital (0, > 0 through 15 minutes, > 15 through 30 minutes, > 30 minutes), travel time to nearest primary care physician (0, > 0

TABLE 1—Study Population, Characteristics, and Crude Event Rates: Residents and Zip Codes of the 72 Hospital Service Areas of Maine, New Hampshire, and Vermont

Population Characteristics (Unit of Observation)	Adults, 1989, Aged ≥18 Years: Persons No.	%	Discharges/1000: All Medical DRGs	Discharges/1000: Four Low-Variation Conditions[a]	Deaths/1000, Medicare Enrollees	Children, 1985 through 1989, Aged ≤17 Years: Person-Years No.	%	Discharges/1000, All Medical DRGs
Travel time to nearest hospital (zip code), min								
0	751 930	36	80.7	8.2	51.8	1 213 580	34	31.2
1–15	643 603	31	63.7	6.5	47.0	1 094 120	31	25.9
16–30	489 080	23	62.3	6.4	46.9	853 230	24	25.9
> 30	203 104	10	71.1	7.7	47.0	377 503	11	25.1
Travel time to nearest primary care physician (zip code), min								
0	1 672 132	80	71.0	7.3	49.8	2 706 512	76	28.2
1–10	276 646	13	62.5	6.5	43.8	562 050	16	25.0
11–20	83 121	04	75.4	6.8	48.1	166 331	05	27.6
> 20	55 818	03	74.7	7.8	45.1	103 540	03	26.7
Bed supply (hospital service area), beds/1000								
≤ 2.3	696 489	33	63.2	6.6	48.5	1 176 361	33	27.1
2.31–3.45	708 472	34	75.9	8.0	47.8	1 192 153	34	27.7
> 3.45	682 756	33	71.3	7.1	50.4	1 169 919	33	28.1
Median household income (zip code)								
≤ $26 500	698 282	33	82.8	8.3	50.5	1 262 709	36	30.8
> $26 500–$32 000	691 429	33	68.1	7.2	49.1	1 156 762	33	26.7
> $32 000	698 006	33	59.6	6.1	46.4	1 118 962	32	25.0
Hospital service area type (hospital service area)								
Academic medical center	319 430	15	58.5	5.7	46.1	521 405	15	20.4
Community hospital	1 768 287	85	72.3	7.5	49.3	3 017 028	85	28.9
Nursing home patients (zip code)								
Some	1 280 910	61	74.8	7.9	51.3	...		...
None	806 807	39	62.8	6.1	44.3	...		...
Rural (zip code)								
Metropolitan	882 285	42	62.4	6.2	48.6	1 432 082	40	26.3
Nonmetropolitan	1 205 432	58	75.9	8.0	49.1	2 106 351	60	28.5
Gender (individual)								
Female	1 088 423	52	70.1	8.1	43.9	1 727 952	49	25.9
Male	999 294	48	70.2	6.2	56.3	1 810 481	51	29.3
Age (individual)[b]								
Younger	1 191 905	57	29.4	0.6	...	977 129	28	51.7
Middle	525 091	25	73.4	6.5	...	933 131	26	15.8
Older	370 721	18	196.8	29.6	48.9	1 628 173	46	19.9
Total	2 087 717	100	70.2	7.2	...	3 538 433	100	27.6

Note. DRG = diagnosis-related group.
[a]Acute myocardial infarction, cerebral vascular accident, major cancer surgery, and hip fracture.
[b]Adult: younger age, 18–44; middle, 45–64; older, ≥ 65 years. Pediatric: younger age, 0–4; middle, 5–9; older, 10–17 years.

through 10 minutes, > 10 through 20 minutes, > 20 minutes), bed supply (by tercile), median household income (by tercile), presence of an academic medical center in the hospital service area, presence of nursing home patients in the hospital service area (for adults), and nonmetropolitan zip code. Two first-order interactions (age × sex, bed supply × academic medical center) were also included in all models. All of these variables have been shown in previous studies to increase the likelihood of hospitalization and could confound the interpretation of crude discharge rates.[2,23,31] Travel time interactions (travel time × age, travel time × median household income, travel time × metropolitan residence, travel time × academic medical center) were assessed by means of a likelihood ratio pooled test of significance.[32] Point esti-

TABLE 2—Adjusted Rate Ratios and 95% Confidence Intervals for the Likelihood of Hospitalization for the Most Common Medical Diagnosis-Related Groups, by Travel Time to the Nearest Hospital

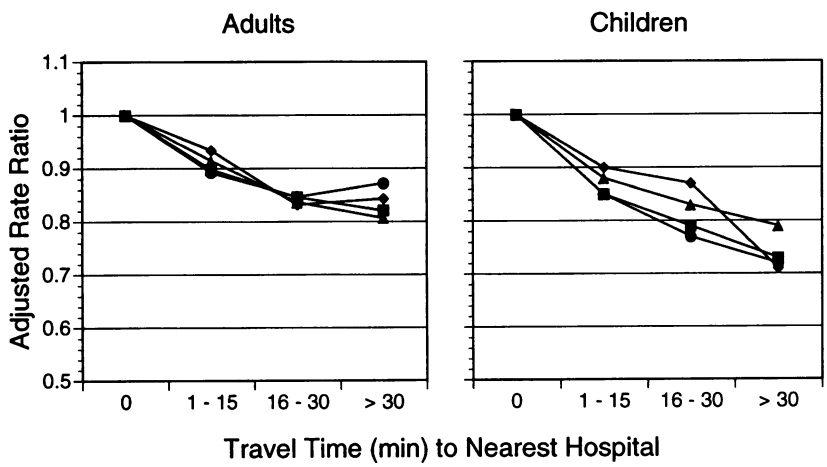
		Adjusted Rate Ratios[a] by Travel Time to Nearest Hospital						
		1–15 min		16–30 min		> 30 min		
	0 min[b]	Ratio	95% CI	Ratio	95% CI	Ratio	95% CI	*P* for Trend
Adult DRGs (1989)								
Heart failure and shock	1.0	0.89	0.83, 0.96	0.85	0.78, 0.92	0.87	0.78, 0.97	.009
Angina	1.0	0.90	0.83, 0.97	0.85	0.77, 0.93	0.82	0.73, 0.92	.006
Medical back	1.0	0.92	0.83, 1.01	0.84	0.75, 0.94	0.81	0.70, 0.93	< .001
Esophagitis and gastroenteritis without comorbidity and/or complications	1.0	0.93	0.85, 1.02	0.84	0.75, 0.93	0.84	0.74, 0.97	.004
Medical admissions	1.0	0.89	0.87, 0.91	0.83	0.82, 0.86	0.85	0.82, 0.88	< .001
Pediatric DRGs (1985–1989)								
Bronchitis and asthma	1.0	0.85	0.79, 0.92	0.79	0.73, 0.86	0.73	0.65, 0.81	< .001
Esophagitis and gastroenteritis	1.0	0.85	0.80, 0.90	0.76	0.72, 0.82	0.72	0.66, 0.79	< .001
Simple pneumonia	1.0	0.88	0.82, 0.95	0.83	0.76, 0.89	0.79	0.71, 0.87	< .001
Viral illness and fever, unknown origin	1.0	0.90	0.83, 0.97	0.87	0.79, 0.95	0.71	0.63, 0.81	< .001
Medical admissions	1.0	0.86	0.84, 0.89	0.84	0.81, 0.87	0.78	0.74, 0.81	< .001

Note. CI = confidence interval; DRGs = diagnosis-related groups.
[a]From Poisson regression controlling for age, sex, bed supply, median household income, residence in academic medical center hospital service area, and residence in nonmetropolitan area. Models for adults also included residence in zip code with nursing home patients.
[b]Zero minutes is reference value for regression models and indicates that the population is located in a zip code with a hospital.

mates and confidence intervals for the rate ratios were obtained by exponentiating the corresponding regression parameters.

We incorporated variance overdispersion in the estimates of standard errors to account for clustering of hospitalizations within strata as well as multiple hospitalizations of the same patient.[33] The effect of this adjustment was to increase the width of the usual confidence intervals by a factor of between 1.00 and 1.97. The discharge analyses used the NLIM procedure in the statistical package SAS.[34]

Mortality rates were analyzed by means of the logistic regression in a similar fashion.[35] Finally, we used multiple regression models to study the relationship between travel time and the logarithm of the length of stay for hospitalized patients. In these models, the individual hospitalization was the unit of analysis. Estimates were expressed in terms of their proportional effects on length of stay by exponentiating the regression parameters, as above. All statistical tests were performed at the 5% level of significance unless otherwise specified.



Note. For Adults, ● = heart failure and stroke; ◆ = esophagitis and gastroenteritis without complications; ■ = angina; ▲ = medical back. For children, ● = esophagitis and gastroenteritis; ◆ = viral illness and fever of unknown origin; ■ = bronchitis and asthma; ▲ = simple pneumonia. Covariates in Poisson regression model include age, sex, bed supply, median household income, residence in academic medical center hospital service area, residence in nonmetropolitan area, and residence in zip code with nursing home patients (adult model only). Test for trend < .05 in all models.

FIGURE 1—Rate ratios for the likelihood of hospitalization for common medical diagnoses, by categories of travel time, in northern New England.

Results

Distance to Medical Care

Residents in the study region resided in zip codes with widely varying travel times (Table 1). Thirty-four percent of the children and 36% of the adults lived in zip codes with at least one hospital. The proportion of residents exceeding the commonly used medical care access standard of 30 minutes[2,36,37] was approximately 10%. Travel times greater than 30 minutes were found for 16% of nonmetro-

TABLE 3—Adjusted Rate Ratios, Adjusted Odds Ratios, and 95% Confidence Intervals for the Likelihood of Hospitalization for Low-Variation Conditions in Adults and Death in Medicare Enrollees, by Travel Time to Nearest Hospital

	Ratios[a] by Travel Time to Nearest Hospital							
		1–15 min		16–30 min		> 30 min		
	0 min[b]	Ratio	95% CI	Ratio	95% CI	Ratio	95% CI	*P* for Trend
		Adjusted rate ratios[a]						
Low-variation conditions								
Acute myocardial infarction	1.0	0.99	0.91, 1.08	0.94	0.85, 1.05	1.06	0.93, 1.20	.95
Cerebral vascular accidents	1.0	0.96	0.88, 1.05	0.89	0.80, 0.99	0.94	0.82, 1.07	.06
Major cancer surgery	1.0	0.93	0.85, 1.02	0.86	0.77, 0.96	0.97	0.85, 1.11	.22
Hip fracture	1.0	0.92	0.82, 1.04	0.93	0.81, 1.07	0.94	0.78, 1.12	.57
Combined low-variation conditions	1.0	0.96	0.91, 1.01	0.91	0.86, 0.96	0.98	0.91, 1.06	.09
		Adjusted odds ratios[a]						
Total Medicare deaths	1.0	0.98	0.94, 1.02	1.01	0.96, 1.06	0.99	0.93, 1.05	.93

Note. CI = confidence interval.
[a]From Poisson (hospitalization) and logistic regression (mortality) adjusted for age, sex, bed supply, median household income, residence in academic medical center hospital service area, residence in nonmetropolitan area, and residence in zip code with nursing home patients.
[b]Zero minutes is the reference value for regression models and indicates population is located in zip codes with a hospital.

politan and 2% of metropolitan residents. Travel times to the nearest primary care physician were shorter than to hospitals. Seventy-nine percent of the population lived in zip codes with a primary care physician, and only 3% resided farther than 20 minutes from a primary care physician. The Spearman rank correlations for travel time to the nearest hospitals and to the nearest primary care physician were 0.38 for adults and 0.39 for children.

Medical Hospital Discharges

For both adult and pediatric medical causes of hospitalization, discharge rates declined with increasing distance to hospitals (Table 1). Adults living within zip codes with a hospital had the highest discharge rates (80.7 per thousand) compared with those living 1 through 15 minutes (63.7 per thousand), and 16 through 30 minutes (62.3 per thousand) away. Adults living more than 30 minutes from the nearest hospital had a discharge rate of 71.1 per thousand, reflecting a U-shaped curve with distance. For children, a stepwise relationship was observed, with discharge rates decreasing from 31.2 per thousand for those living in a zip code with a hospital to 25.1 per thousand for those residing at more than 30 minutes travel time.

The relationship between travel time and hospital discharges persisted after stratification by population and area characteristics (available from authors). Across all strata levels, adult medical discharge rates were highest for those living within a zip code with a hospital and lowest for those residing with a travel time of 16 through 30 minutes. A stepwise decline by distance to hospitals was observed for children across all strata levels.

After the known predictors of hospitalization were controlled for, the risk of medical hospitalization decreased with increasing travel time for both children and adults (Table 2, Figure 1). The rate ratio for residents with a travel time of greater than 30 minutes compared with those living in a zip code with a hospital was 0.85 (95% confidence interval [CI] = 0.82, 0.88) for adults (15% lower odds of hospitalization) and 0.78 (95% CI = 0.74, 0.81) for children (13% lower odds of hospitalization) for all medical diagnosis-related groups combined (test for trend, $P < .001$). The decreased likelihood of hospitalization with increasing distance was also observed for all eight of the individual diagnosis-related groups studied (test for trend, $P < .01$).

Similar results were obtained when travel time to the nearest primary care physician was used as the sole travel variable. However, when this variable was added to the model that measured travel time to the nearest hospital, the overall model fit did not significantly change (likelihood ratio test, $P > .05$), and the additional effect of potential travel to physician became nonsignificant.

The higher risk of hospitalization for those living closer to hospitals raised the possibility that these patients were discharged with shorter lengths of stay and that thus, there was no overall difference in the use of hospital services. Regression models failed to detect a significant association between lengths of stay and distance with the exception of two pediatric study groups: all medical discharges ($P = .0002$) and pediatric asthma/bronchitis ($P = .009$). In both of these cases, the actual effect of distance was small—those living in a zip code with a hospital had lengths of stay 4% greater than those residing at more than 30 minutes (about 4 hours for all medical discharges and 2 hours for asthma/bronchitis). Therefore, hospital utilization as a function of distance is well reflected by discharge rates.

Adult Low-Variation Discharges and Mortality

In the four low-variation conditions studied, discharge rates were also highest in zip codes that included a hospital (Table 1). Crude discharge rates generally declined with travel time, but not in a clear stepwise fashion. The travel time effect, however, was not significant after adjustment for risk factors for hospitalization (Table 3).

Medicare mortality was 9.3% higher in zip codes with hospitals (51.8 vs 47.0 per thousand) (Table 1). After adjustment for confounders—in particular, the higher likelihood of nursing home patients residing close to hospitals—mortality rates were not influenced by proximity to the nearest hospital in the elderly population (Table 3).

Discussion

We found that residents of northern New England who lived farther from the hospital were substantially less likely to be hospitalized for medical illness, in spite of their relatively high geographic access to primary care physicians. We observed this effect for medical illness where outpatient treatment is often a reasonable alternative; notably, such illnesses are also the most common causes of hospitalization. For the conditions in which the medical consensus on the need for hospitalization is strong, we observed only a slight and nonsignificant decline in hospitalization rates with increasing distance. Greater distance from the hospital was not associated with an increased risk of death in the Medicare population.

The higher rates of hospitalization in populations residing closer to hospitals are unlikely to be from higher illness rates. Our results indicate that adults with lower health status did tend to live closer to hospitals, as evidenced by higher crude hospitalization rates for the low-variation conditions and higher crude mortality in the Medicare enrollees. Adults residing in nursing homes are the largest high-risk populations and often live within the same zip code as the hospital. When the regression models controlled for the presence of nursing home populations, mortality rates and the likelihood of hospitalization for conditions necessitating inpatient care, such as acute myocardial infarctions and hip fractures, did not differ by distance. Without distance effects observed for the most serious causes of hospitalization or for mortality, it is very unlikely that health status confounds the adjusted results for the medical conditions where hospitalization is often discretionary. Furthermore, similar associations between distance and hospitalization were observed for children. Families of some children with chronic illness like cystic fibrosis and cancer might move nearer to medical facilities, but these are infrequent causes of hospitalization. Most pediatric hospitalizations result from acute illness in otherwise healthy children, situations in which neither the illness nor the inpatient stay can be anticipated.

Differences in socioeconomic status are also unlikely to explain the differences in utilization rates that we observed. We found strong effects of distance on utilization across all strata of all variables. Living farther from the hospital was associated with lower hospitalization rates in metropolitan as well as nonmetropolitan populations, in affluent as well as poor communities, and in children as well as the elderly. Despite the consistency of effect observed across known and measurable covariates, other factors may still confound or modify the association of distance and hospital utilization.

Our study uses an ecological design. Administrative databases recording hospital discharges contain only limited patient characteristics, and it was necessary to confer area characteristics on age–sex groups within zip codes to examine the experience of the study region. The limitations of attributing area characteristics to individuals are well known[38,39] and are pertinent only for the variables median household income, travel time, and presence of nursing home patients. We have minimized heterogeneity by using the smallest units of observation feasible: the age–sex groups in zip codes. The limitations of an ecologic design do not pertain to such area characteristics as bed supply, academic medical center hospital service area, and metropolitan residence since areas are the logical units of "exposure" for these community characteristics.[40] The consistent effect of distance across the strata of these covariates, as well as age and diagnostic groups, supports our findings despite the limited individual characteristics included in the models.

A further limitation in the hospital databases is that patient-level data are insufficient to distinguish first admissions from readmissions, a common problem in studies utilizing "all-payor" hospital data sets.[41] This clustering of events requires specific model parameters to account for the increased variance, such as the overdispersion factor estimated for the regression models, but will not bias the point estimate.

In our study, the measure of travel time is a proxy for the actual potential travel of residents. Since this method aggregates exposure and assumes that patients are traveling from home to their nearest provider, the study may have underestimated travel time effects or may conceal more complex travel time effects. Misspecifications of travel time exposure will tend to reduce the strength but not the direction of the effects we have observed. Caution should also be exercised in generalizing these findings to other regions of the country. Travel times in northern New England are modest compared with other rural[42] regions. On the other hand, the potential travel time for populations in northern New England is very similar to most small metropolitan and suburban communities in the United States.

Our finding of a strong association between distance to hospital and the frequency of hospitalization does not, by itself, reveal the mechanism of the effect. One possible explanation is that proximity influences the likelihood of patients' contacting the health care system and the means they use or the rate at which physicians recommend (and patients accept) hospitalization for conditions where there is substantial uncertainty about the need for it. Whether this is due to more frequent use of emergency rooms, where physicians may be less familiar with a patient's health history, or to some other factor is unclear from our data.

Regardless of the explanation, it is difficult to conclude that the observed pattern of hospital use is either rational or equitable. If one assumes that local population rates are optimal, then residents distant from hospitals are disadvantaged. On the other hand, if populations just 15 minutes away are receiving adequate medical care, then local residents may be hospitalized too frequently. This irrational utilization (i.e., not based on need) is consistent with prior research demonstrating that the supply and delivery of medical resources are frequently inconsistent with the needs of populations. For example, several studies have demonstrated that area variation in hospitalization rates is partly explained by differences in the supply of inpatient resources, such as the per capita bed supply.[20,23,25,43,44] There is no consensus on the necessary bed supply for a population, and hospitals are rarely built in response to data about population health needs. Similarly, McClellan and colleagues demonstrated that cardiovascular procedures in Medicare patients with myocardial infarctions are correlated with variables unrelated to health status, such as distance to a facility performing the procedure.[17] Mortality rates did not appear to be improved by the differential use of invasive procedures.

Hospitals are important and expensive resources. If one assumes that people living 15 through 30 minutes away were receiving a reasonable level of inpatient care, then 12 000 discharges could be saved annually in northern New England.

Regardless of whether this pattern of utilization represents excess utilization in those living near hospitals or inadequate delivery of services to those at greater distance, the mechanisms leading to the difference should be investigated further. In the interim, one should not assume that greater geographic availability of medical resources necessarily leads to desirable patterns of utilization or measurably improved health outcomes. □

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References

1. Lee PR, Benjamin AE. Health policy and the politics of health care. In: Williams SJ, Torrens PR, eds. *Introduction to Health Services.* 4th ed. Albany, NY: Delman Publishers Inc; 1993:399–420.
2. *Health Care in Rural America.* Washington, DC: Office of Technology Assessment. 1990. OTA publication OTA H-434.
3. Shannon GW, Bashshur RL, Metzner CA. The concept of distance as a factor in accessibility and utilization of health care. *Med Care Rev.* 1969;26:143–161.
4. McGuirk MA, Porell FW. Spatial patterns of hospital utilization: the impact of distance and time. *Inquiry.* 1984;21(spring): 84–95.
5. Weiss JE, Greenlick MR, Jones JF. Determinants of medical care utilization: the impact of spatial factors. *Inquiry.* 1971;8(4): 50–57.
6. Luft HS, Garnick DW, Mark DH, et al. Does quality influence choice of hospital? *JAMA.* 1990;263:2899–2906.
7. Roghmann KJ, Zastowny TR. Proximity as a factor in the selection of health care providers: emergency room visits compared to obstetric admissions and abortions. *Soc Sci Med.* 1979;13D:61–69.
8. Hays SM, Kearns RA, Moran W. Spatial patterns of attendance at general practitioner services. *Soc Sci Med.* 1990;31:773–781.
9. Brooks CH. Associations among distance, patient satisfaction, and utilization of two types of inner-city clinics. *Med Care.* 1973;11:373–383.
10. Shannon GW, Dever GEA. *Health Care Delivery: Spatial Perspectives.* New York, NY: McGraw-Hill; 1974.
11. Jehlik PJ, McNamara RL. The relation of distance to the differential use of certain health personnel and facilities and to the extent of bed illness. *Rural Sociol.* 1952;17: 261–265.
12. Girt JL. Distance to general medical practice and its effect on revealed ill-health in a rural environment. *Can Geographer.* 1973;17:154–166.
13. Luft HS, Hershey JC, Morrell J. Factors affecting the use of physician services in a rural community. *Am J Public Health.* 1976;66:865–871.
14. Shannon GW, Arcury TA. The journey to birth: medical and geographical patterns of births to women of a rural Kentucky county, 1911–1980. *Am J Prev Med.* 1985;1:30–34.
15. Greenberg ER, Chute CG, Stukel T, et al. Social and economic factors in the choice of lung cancer treatment: a population-based study in two rural states. *New Engl J Med.* 1988;318:612–617.
16. Greenberg ER, Dain B, Freeman D, Yates J, Korson R. Referral of lung cancer patients to university hospital cancer centers: a population-based study in two rural states. *Cancer.* 1988;62:1647–1652.
17. McClellan M, McNeil BJ, Newhouse JP. Does more intensive treatment of acute myocardial infarction in the elderly reduce mortality? analysis using instrumental variables. *JAMA.* 1994;272:859–866.
18. Wennberg J, Gittelsohn A. Small area variation in health care delivery. *Science.* 1973;182:1102–1108.
19. Wennberg JE. Should the cost of insurance reflect the cost of use in local hospital markets? *N Engl J Med.* 1982;307:1374–1381.
20. Wennberg JE, Freeman JL, Culp WJ. Are hospital services rationed in New Haven or over utilized in Boston? *Lancet.* 1987;1: 1185–1189.
21. O'Connor GT, Plume SK, Olmstead EM, et al. A regional prospective study of in-hospital mortality associated with coronary artery bypass grafting. *JAMA.* 1991; 266:803–809.
22. Wennberg JE, Gittelsohn AM. *A Small Area Approach to the Analysis of Health System Performance.* Washington, DC: US Dept of Health and Human Services; 1980. Health Planning Methods and Technology series. DHHS publication HRP-0102101.
23. Goodman DC, Fisher ES, Gittelsohn A, Chang C, Fleming C. Why are children hospitalized? the role of non-clinical factors in pediatric hospitalizations. *Pediatrics.* 1994;93:896–902.
24. Wennberg JE, McPherson K, Caper P. Will payment based on diagnoses-related groups control hospital costs? *N Engl J Med.* 1984;311:295–300.
25. Fisher ES, Wennberg JE, Stukel TA, Sharp SM. Hospital admission rates for cohorts of Medicare beneficiaries in Boston and New Haven. *N Engl J Med.* 1994;331:989–995.
26. Wennberg JE, Roos N, Sola L, Schori A, Jaffe R. Use of claims data systems to evaluate health outcomes: mortality and reoperation following prostatectomy. *JAMA.* 1987;257:933–936.
27. American Hospital Association. *Annual Survey of Hospitals Data Base.* Chicago, Ill: American Hospital Association; 1989. Machine-readable data file.
28. *City Reference File 1987.* Washington, DC: Bureau of the Census; 1988. Machine-readable data file.
29. *1990 Decennial Census.* Washington, DC: Bureau of the Census; 1993. Machine-readable tape STF3b.
30. McCullagh P, Nelder JA. *Generalized Linear Models.* New York, NY: Chapman & Hall; 1983.
31. *Health, United States, 1990.* Washington, DC: National Center for Health Statistics; 1991. DHHS publication PHS 91-1232.
32. Aitkin M. A note on the selection of log-linear models. *Biometrics.* 1980;36: 173–178.
33. Donner A, Donald A. The analysis of data arising from a stratified design with cluster as the unit of randomization. *Stat Med.* 1987;6:43–52.
34. SAS Institute Inc. *SAS/STAT Software, Release 6.07.* Cary, NC: SAS Institute Inc; 1992. SAS technical report P-229.
35. Hosmer DW, Lemeshow S. *Applied Logistic Regression.* New York, NY: Wiley & Sons; 1989.
36. Criteria for designation of health manpower shortage areas. *Federal Register* 45:75996–76003.
37. Bosnac EM, Parkinson RC, Hall DS. Geographic access to hospital care: a 30-minute travel time standard. *Med Care.* 1976;14:616–624.
38. Hennekens CH, Buring JE. Descriptive studies. In: Mayrent SL, ed. *Epidemiology in Medicine.* Boston, Mass: Little Brown & Co Inc; 1987:101–131.
39. Susser M. The logic in ecological: I. the logic of analysis. *Am J Public Health.* 1994;84:825–829.
40. Poole C. Editorial: ecologic analysis as outlook and method. *Am J Public Health.* 1994;84:715–716.
41. Diehr P, Cain K, Connell F, Volinn E. What is too much variation? the null hypothesis in small-area analysis. *Health Serv Res.* 1990;24:741–771.
42. Williams AP, Schwartz WB, Newhouse JP, Bennett BW. How many miles to the doctor? *N Engl J Med.* 1983;309:958–963.
43. Brewer WR, Freedman MA. Causes and implications of variation in hospitalization utilization. *J Public Health Policy.* 1982;3: 445–454.
44. Wilson PA, Griffith JR, Tedeschi PJ. Does race affect hospital use? *Am J Public Health.* 1985;75:263–269.